CHAPTER 11

CD-ROM STORAGE

INTRODUCTION

As the uses of computers expand, the need for disseminating large amounts of information to multiple users also increases. This information can be software or raw data. The use of a CD-ROM is ideally suited for these purposes. In the Navy, CD-ROMs are currently being used in several areas including the Naval Intelligence Processing System (NIPS) and the Naval Command and Control Systems.

After completing this chapter, you should be able to:

- **Describe the physical characteristics of a CD-ROM**
- **Describe the storage structure of the data on a CD-ROM**
- **Describe the operation of a CD-ROM drive**
- **Describe the different applications that use CD-ROMs**

The evolution of CD-ROM technology has expanded to the point that multimedia CD-ROMs are now in use. A multimedia CD-ROM is a disc that stores digital data, digitized audio data, and digitized video data. The same CD-ROM drive can be used for all three functions; in many cases, using the computer to drive the audio and video portions of the CD-ROM.

NOTE: *Disc* or *disk?* The original audio compact disc distributors referred to the CD as a *disc*, while the manufacturers of floppy disks used the *disk* spelling. When the compact disc was developed as a digital storage medium, the manufacturers kept the *disc* spelling. In this manual, we stay with the current use of disc when referring to the CD-ROM compact disc.

The CD-ROM for use as a data storage medium was a result of the popularity of the audio compact disc. The major problem that had to be overcome was that digital data storage had to be much more precise than digital audio. A reliable data encoding and error correction scheme was developed to solve this problem.

This chapter will introduce you to the CD-ROM and the CD-ROM drive.

TOPIC 1—THE COMPACT DISC

The compact disc is capable of storing any type of digital data. The information is stored on the disc by etching a series of *pits*, or little holes, between flat spots. The flat spots on the disc are called *lands*. The information is stored on a continuous spiral track that starts at the inside of the disc and travels toward the outer edge.

PHYSICAL CHARACTERISTICS OF A COMPACT DISC

The base of a CD is a clear, hard plastic, known as polycarbonite. The CD is molded from a master that forms the pits and lands. The top of the plastic disc is coated with a reflective material, such as aluminum, that reflects the light of the reading laser. The entire disc is coated with a protective lacquer and a label is printed on the top of the disc.

Figure 11-1 shows a typical compact disc. The diameter of the disc is 120 mm. The center hole is 15 mm in diameter. The area closest to the center hole is the clamping area, and no data is written in this area. The clamping area is generally 26 mm to 33 mm wide, measured from the center of the disc.

The data area is approximately 38 mm wide and is divided into three sections. Figure 11-2 illustrates a cross section of a CD-ROM's data area. The table of contents for the entire disc occupies the first 4 mm of the data area. The next section is the program area, and occupies 33 mm if the disc is filled to capacity. The third area of the disc is the lead-out area and it is used to tell the drive it has reached the end of the disc. No data is written on the outer edge of the disc; this allows for handling.

ADVANTAGES AND DISADVANTAGES OF CD-ROM

CD-ROM has several advantages over magnetic media in the dissemination of digital information. The greatest advantage is the amount of data. A single CD-ROM can store over 500 megabytes. The data on a CD-ROM can also be a mixture of digital information. The CD-ROM can store audio, video, graphics, text, and programs. CD-ROMs that combine different types of data (audio, graphics, and so on) are known as CD-I, or compact disc-interactive.

The CD-ROM is extremely durable and difficult to damage. Since the CD-ROM is an optical storage medium, the read head never comes in contact with the disc. Therefore, it does not suffer from damage caused by head crashes as magnetic disk media do.

The CD-ROM does have disadvantages. Because of the way the CD-ROM drive reads data, the access time is much slower than for a high performance fixed disk system. The CD-ROM is designed to hold a large amount of data for a large number of users. The initial high cost of producing the master disk precludes sending unique information to just one or two users.

DATA STORAGE STRUCTURE

Information is written on a CD-ROM as a series of pits and lands and read from the disk by detecting reflections of a laser from the lands. When the laser

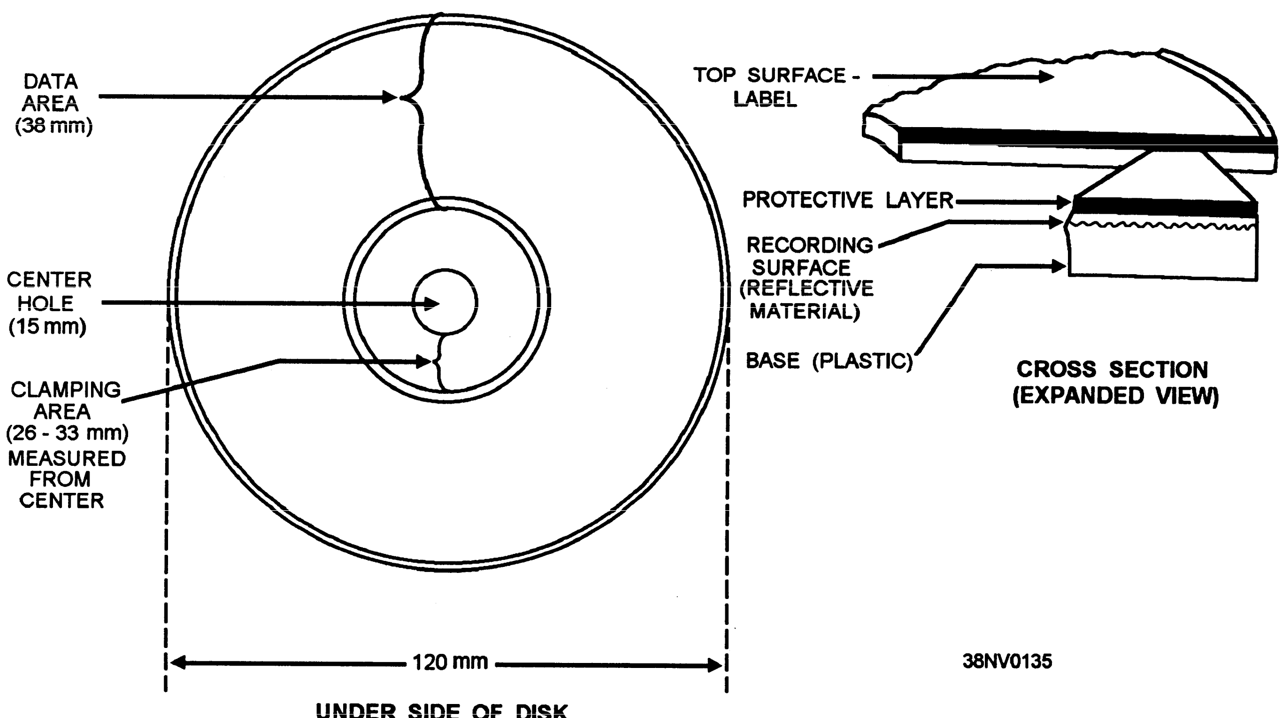

Figure 11-1.—A typical compact disc.

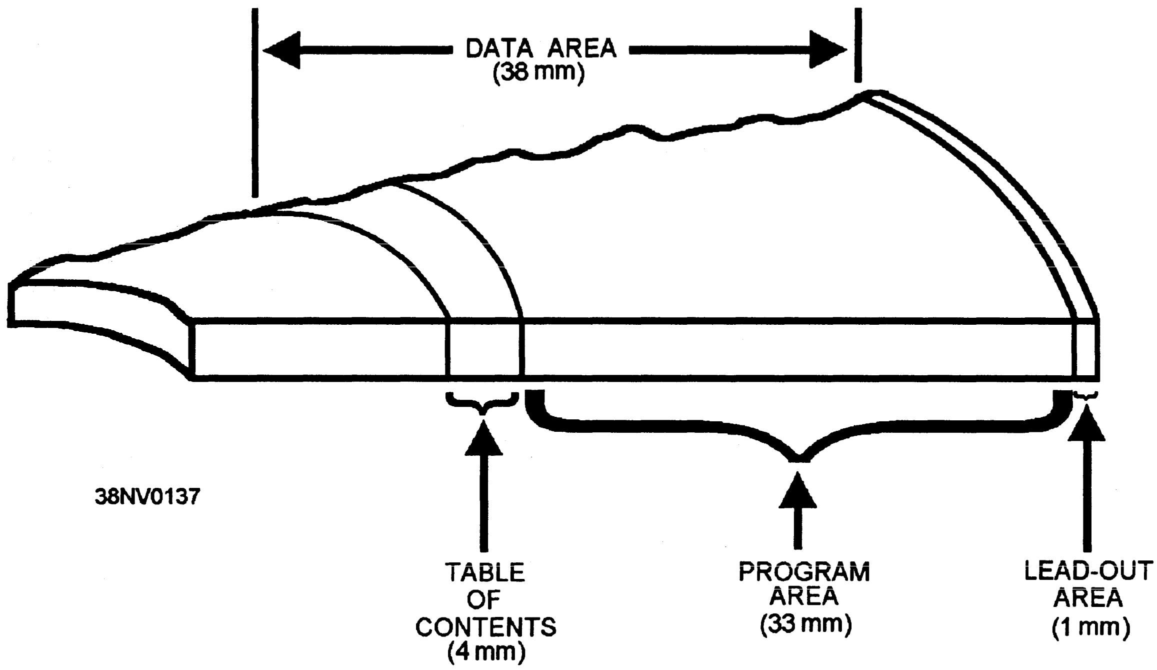

Figure 11-2.—A cross section of CD-ROM with data areas defined.

beam is over a land, the light is reflected back to a photodetector. When the laser beam is over a pit, the light is defused and not detected by the photodetector.

The data on a CD-ROM is written in a continuous spiral, much like the groove of a phonograph record, and was adapted from the CD audio standard. The data track is 0.5 micrometers wide. The space between the turns of the track is 1.6 micrometers. This equates to a track density of 16,000 tracks per inch (tpi) and a maximum of 640 megabytes per disc. The actual capacity of a CD-ROM is dependent on the mode used to produce the disc. Two modes of recording data on a CD-ROM are currently in use. Mode 1 writes 2,048 data bytes per sector, followed by error connection codes. Mode 2 writes 2,336 data bytes per sector and eliminates the error correction codes.

In chapter 2 of this manual, you saw that a disk is divided into tracks and sectors. The disk rotation speed is constant and data is accessed by defining the track and sector. On a CD-ROM disc, the data is also stored in sectors of 512 bytes. The size of the sectors on a CD-ROM disc remains the same, regardless of the physical location of the sector. The spiral increases in size as it winds toward the outer edge of the disc, thus the number of sectors per rotation increases.

Constant Linear Velocity

Constant linear velocity is the technique that the CD-ROM drive uses to access data from a disc. To properly read the data from the disc, the speed of the disc must decrease as the laser moves to the outer edge of the disc. Rotation speed of the disc while reading the inner tracks is approximately 500 rpm. As the read head moves to the outer edge of the disc, rotation speed decreases to 200 rpm.

Sector addresses on CD-ROM are adaptations of the CD audio standard and are recorded on the disc in terms of minutes, seconds, and sector (minute:second:sector). To find a sector, the read head is slewed to the approximate position of the data, the rotation speed of the disc is adjusted, and the drive reads the position data in the header of the next sector to determine the location of the read head. The read head is then fine positioned to the desired location by repeating this procedure until the proper sector is found. This process can lead to access times of about 1 second. Once the proper sector is found, data transfer is 150 to 300 kilobytes per second, depending on the type of CD-ROM drive. These relatively slow access times and data transfer rates are among the biggest problems with CD-ROMs. Manufacturers are striving to improve these rates and have introduced double-speed, triple-speed, and higher multiple-speed drives.

Eight-to-Fourteen Modulation

The eight-to-fourteen modulation technique for encoding data on a CD-ROM disc was developed to increase the accuracy of the data read from the disc. Each byte has a corresponding 14-bit code. When the disc is manufactured, the data is recorded in the eight-to-fourteen code. When the data is read from the disc, the conversion from coded information back to a byte is accomplished from a look-up table. This table is in a ROM on the disc drive. Three additional bits are added to each 14-bit code to provide separation and low-frequency suppression.

TOPIC 2—CD-ROM DRIVES

Although still relatively new, CD-ROM drives are becoming popular as a tertiary storage media device. CD-ROM drives vary by manufacturers in the method the data is read from the disk and the laser system used, but the basic operation is similar. In this section, we cover the common components and operation of CD-ROM drives. The basic components of the CD-ROM drive are the following:

- Optical head
- Turntable
- Computer interface section
- Microprocessor based control system

Figure 11-3 shows a basic block diagram of a CD-ROM drive.

OPTICAL HEAD

The optical head contains the circuitry to read the data from the disc. This unit usually consists of four main subassemblies; (1) the laser, used to generate a light beam; (2) a lens system, to focus the laser beam on the disc and to direct the reflected light to the photodetector; (3) a series of servomotors that controls the position of the laser and lenses to ensure proper tracking and focus; and (4) a photodetector, that evaluates the reflected light and converts the light to electrical impulses.

Laser

The laser in a CD-ROM drive is generally a small injection laser diode that emits light in the infrared band. An injection laser is energized by injecting it with an electric current across a semiconductor junction. Injection laser diodes are the smallest laser light source. They are highly efficient and mass produced.

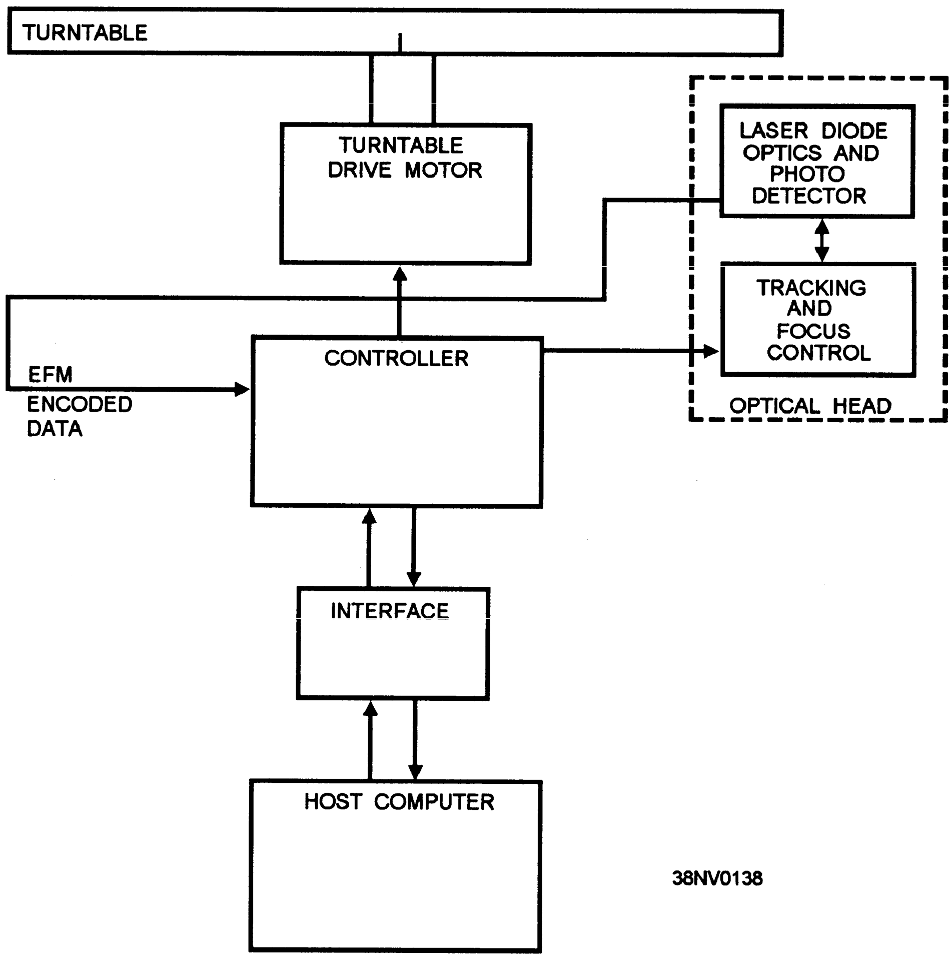

Figure 11-3.—A CD-ROM drive block diagram.

The laser beam is directed to the disc using several different methods, depending on the system preferred by the manufacturer. One type of system deflects the laser beam off a semitransparent mirror, through the lenses, and onto the disc. When the laser beam strikes a land, the reflected light passes through the semitransparent mirror into the photodetector.

Lenses

The lenses in a CD-ROM drive are used to focus the laser beam onto the compact disc. When the laser is turned on, the beam tends to diverge as it travels away from the source. The beam first passes through a **collimating lens** that reduces the divergence. The beam then passes through the **objective lens,** where it is focused onto the surface of the disc.

The final component used to focus the beam on a compact disc is the disc itself. The diameter of the laser beam as it exits the objective lens is approximately 1 mm. The refractive properties of the clear plastic material of the disc further focus and reduce the diameter of the laser beam so that it is 1.0 µm when it reaches the information surface of the disc. This fine focus of the laser is one of the factors of the high durability and reliability of the compact disc.

Tracking and Focusing

Once the optical head is positioned over the area to be read, a system is needed to properly hold the optical head on the track and maintain proper focus. Errors in tracking and focus can occur because the compact disc is not perfectly flat. Several methods are used to determine tracking and focus.

In the optical head system described earlier in this chapter, the reflected laser beam passes through the semitransparent mirror. The reflected laser beam is next split into two beams by a prism. These two beams are directed to the photodetector. The photodetector consists of four photodiodes. Figure 11-4 shows how the reflected light strikes the photodiodes if the tracking

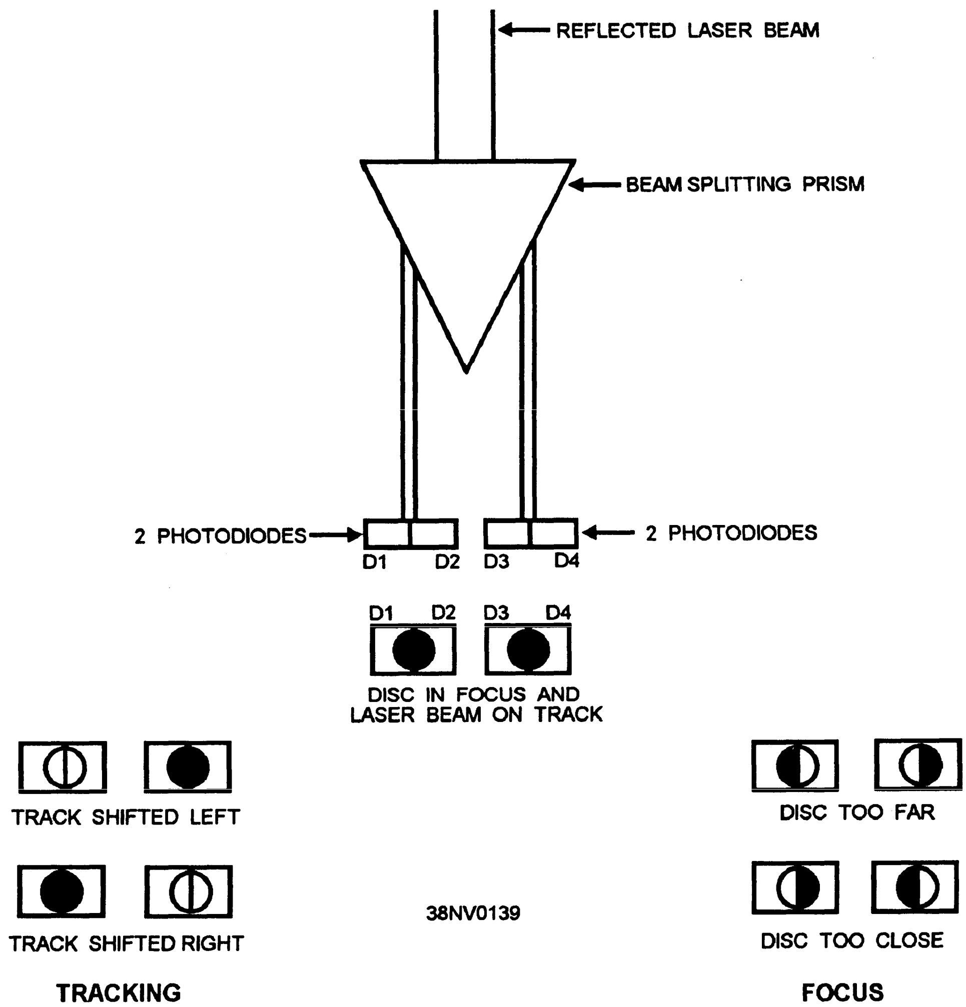

Figure 11-4.—Photodiodes detecting tracking and focus of the laser beam.

is off to the left, off to the right, or on track. The output of the photodiode is fed to a differential amplifier. If the laser is on track, the output voltage of the photodiodes is equal. If the laser beam is off to the left or right, a control voltage will be generated by the differential amplifier that is fed to the track following servo. The amplitude and polarity of this control voltage determines the direction and distance of correction needed.

The same four photodiodes are also used to determine the focus of the laser beam as it strikes the disc. Figure 11-4 shows how the photodiodes will react to detect if the disc is too close to the laser or too far away from the laser, or if the laser is in focus. Again, the output of the photodiodes is fed to an amplifier and correction of focus is made by moving the objective lens.

The output of these four photodiodes is also summed and contains the encoded data on the disc. It is then sent to the control section for decoding.

CD CONTROLLER

The CD controller processes the signals received from the optical head, attempts to correct any errors in the data, and controls the speed of the turntable. The information from the photodiodes that is received by the controller is still encoded in eight-to-fourteen modulation (EFM) data.

The decoding of EFM data is done by the microprocessor. The code addresses a ROM that contains the proper byte for the encoded data. The output of the ROM is stored in a RAM where it is checked for errors.

TURNTABLE

The turntable rotates the disc and is driven by a servomotor. Since the data is written in a continuous spiral, the speed of the turntable must be adjustable so that the information passes over the optical head at a constant speed. The audio CD requires a speed of 1.3 meters per second. This speed was adapted for use in computer applications, but proved to be extremely slow when compared to the processing and data transfer speeds of modem computers. The 2X CD-ROM drive doubled the speed the data track passed over the optical head. The 4X, 6X, and 8X CD-ROM drives spin the disc even faster. The speed multiplication factor is based on the original speed of 1.3 meters per second.

Initial speed adjustments are made when the optical head is positioned in the approximate area of the data. The header of each sector contains a synchronization pulse that is fed into a sawtooth wave generator. The sawtooth wave is fed to the turntable servomotor. The frequency of the wave is used to make fine adjustments to the turntable speed.

INTERFACE SECTION

The interface section provides for the transfer of data between the computer and the CD-ROM drive. Many CD-ROM drives are manufactured with the small computer systems interface (SCSI), although some proprietary interface units are available.

TOPIC 3—CD-ROM APPLICATIONS

Applications that use CD-ROM are rapidly expanding throughout the Navy as systems are updated and the need for reliable storage of large amounts of information increases.

DATABASES AND PUBLICATIONS

CD-ROMs are used in command and control systems, intelligence systems, and the supply system. These applications use large databases. Databases, such as a part number cross-reference list, can significantly reduce the amount of paper storage space required. The CD-ROMs allow information to be quickly retrieved, cross-referenced, and displayed to the user.

Many publications and instructions are also being stored on CD-ROM in an effort to reduce printing and mailing costs. As publications are updated, a new disc is made and sent to all users, who then replace the old disc.

MULTIMEDIA (CD-I) APPLICATIONS

Multimedia or compact disc-interactive (CD-I) applications combine machine executable code (programs), text, audio, video and graphics all on the same CD-ROM. The microprocessor in the CD-ROM drive reads the code at the beginning of each sector to determine if the information that follows is audio, video, graphics, etc. The data is then output on the appropriate channel of the CD-I drive.

SUMMARY—CD-ROM STORAGE

This chapter has introduced you to the CD-ROM and CD-ROM drive. The following information summarize important points you should have learned.

COMPACT DISC— A compact disc is an optical storage medium that can store over 500 megabytes of information.

PHYSICAL CHARACTERISTICS— The disc is 120 mm in diameter with a 15 mm hole in its center. The disc is made of a polycarbonite plastic and coated with a reflective material. Data is stored by etching small holes in the reflective material called pits. The nonetched areas that reflect light are called lands.

ADVANTAGES OF CD-ROM— The advantages of using CD-ROM include:

- Capability to store large amounts of information
- Ability to store data, graphics, audio, and video on the same disc
- Durability—since the optical head of the CD-ROM drive never contacts the disc, there is no danger of a head crash, wear and tear, or accidental data corruption that magnetic media suffer.

DISADVANTAGES OF CD-ROM— The disadvantages of CD-ROMs include:

- High initial cost to produce a single disc
- Slow access and data transfer times compared with high performance fixed disk systems

DATA STORAGE STRUCTURE— Data is stored on a CD-ROM disc in a continuous spiral that starts at the inside of the disc. The spiral is divided into sectors that each hold 512 bytes. Sectors are addressed by minute: second: sector. The number of sectors per revolution of the disc varies as the spiral moves toward the outer edge. The disc drive varies the speed of the disc so that the data passes over the optical head at a constant 1.3 meters per second. This is known as constant linear velocity. Data is encoded on the disc using a method known as eight-to-fourteen modulation. Eight-to-fourteen modulation uses 14 bits to represent 1 byte and aids in error detection and correction.

CD-ROM DRIVES— The CD-ROM drive reads the information stored on a compact disc. The methods used to read data from the disk and the laser systems used in CD-ROM drives vary by manufacturer, but have several similarities. The basic components of the CD-ROM drive are the optical head, a turntable, a computer interface, and a microprocessor-based control system.

OPTICAL HEAD— The optical head is the heart of the CD-ROM drive. It contains a small laser diode to read the data on the disc. The optical head also contains circuitry and optics to control the tracking and focus of the laser beam.

CD CONTROLLER— The CD controller receives the raw data signals from the optical head and converts the eight-to-fourteen encoded data to eight-bit bytes. The controller also prepares the data for transfer to the computer via the interface and controls the speed of the turntable.

INTERFACE SECTION— The interface section controls the data exchange between the computer and the CD-ROM drive. CD-ROM drive interfaces can be SCSI or proprietary systems.

CD-ROM APPLICATIONS— CD-ROMs are used to distribute large amounts of information, such as databases and publications. CD-ROMs can also combine types of information, such as audio, video, data, and graphics. These systems are compact disc interactive or CD-I.